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**The Design and Evaluation of "In Situ" Bioremediation Methods
for the Treatment of Sludges and Soils at Waste Disposal Sites**

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In situ methods for treatment of waste sludges hold great promise for cost-effective, efficient remediation of sludge at waste disposal sites. An example of such a treatment scheme is the landfarming of petroleum-industry sludges, where the biodegradation and volatilization of organics and immobilization of many metals is enhanced. Whereas this treatment is successful for certain contaminants, it is ineffective for others. For sludges containing a broad spectrum of toxic organics and metals, no single remediation scheme is likely to be satisfactory.

The remediation of the diverse and complex sludges from the O.E. MacDougall Waste Disposal Site, near Brockville, Ontario, by current conventional techniques would be very costly. Natural bioremediation techniques were tested in the laboratory, using six representative soils and sludges obtained from the MacDougall site. These techniques require a minimal amount of sludge manipulation, so their use at the site is viewed as a cost-effective method of site cleanup.

Liquid industrial wastes (including solvents and waste oils), sewage sludge and septic tank wastes were disposed of in waste lagoons at the MacDougall site from 1962 to 1981. In October 1987, six samples of soil and sludge were collected for characterization of the organic chemistry of the materials. Three of the samples were brown sandy soil and three were black sludge with a strong sewage odour. No volatile organics were identified in two of the sandy soils. The remaining four samples were found to contain varying concentrations of aliphatic and aromatic hydrocarbons typical of petroleum products and chlorinated hydrocarbons typical of solvents.

In situ bioremediation is dependent upon the number and type of microorganisms present within the sludge or soil. Standard plate counts and culture tube techniques were performed to estimate the number of aerobic, anaerobic (denitrifiers, sulphate-reducers and methanogenic) and sulphate-reducing bacteria present in each material type. All sludge and soil samples contained viable bacteria of the three kinds tested for. Typically, aerobic bacteria were the most abundant, while the sulphate-reducers were the least abundant. Anaerobic bacteria were more abundant in the more contaminated sludges than in the cleaner soils.

The diverse organic chemistry and nature of the microbial population allowed the testing of a number of remedial environments in the laboratory. Bioremediation experiments employed sealed glass bottles containing soil or sludge and distilled water. Various chemical additions were made to selected bottles to establish aerobic, methane-oxidizing, denitrifying, sulphate-reducing or methanogenic conditions within the bottles. At various times, duplicate bottles were analyzed for target aromatics (benzene, toluene, xylenes, trimethylbenzene, cumene, naphthalene) and chlorinated hydrocarbon (tetrachloroethene, trichloroethene) concentrations.



Experiment 1 examined the loss of target compounds under aerobic and methane-oxidizing conditions. The concentrations of aromatics decreased over 147 days, with toluene showing the most significant concentration decrease. Tetrachloroethene and trichloroethene concentrations did not decrease with time. Oxygen concentrations decreased and carbon dioxide concentrations increased simultaneously over time. Methane concentrations showed no decrease, indicating that the methane-oxidizers were not measurably active. The aromatic losses are believed to be the result of aerobic biodegradation.

Experiment 2 was conducted to investigate the bioremediation of the sludges and soils under various anaerobic conditions. Three sludges and one soil were incubated under denitrifying, sulphate-reducing or methanogenic conditions. The most contaminated sludge showed a decrease in tetrachloroethene and trichloroethene concentrations from about 600 ug/g to less than 1 ug/g in 12 days. This decrease was accompanied by an increase in cis-1,2-dichloroethene, indicating a reductive dechlorination breakdown mechanism. Some sludges show decreases in the aromatic content. Decreases are most apparent in toluene concentrations, but trimethylbenzene and naphthalene concentrations also decreased somewhat over time. Aromatic decreases are most significant in microcosms amended with nitrate or sulphate.

In summary, the aromatic hydrocarbons are most easily broken down under aerobic conditions, but may also be degraded anaerobically upon the addition of nitrate and/or sulphate. Tetrachloroethene and trichloroethene seem to be easily broken down to dichloroethene under anaerobic conditions; however, dichloroethene seems to accumulate with time. These results are promising, since they suggest that the natural degradative processes, perhaps acting in sequence and with some stimulation, may provide significant remediation of the sludges at the MacDougall site.